MOUNTAIN BROOK HIGH SCHOOL FINE ARTS CENTER - Moisture Control Case Study

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ABSTRACT

Upon returning to school in the fall, significant problems became evident in the Fine Arts Center of Mountain Brook High School, located near Birmingham, Alabama. In the band department, black mold was found on ceiling tiles, marching band uniforms were damaged beyond repair by mold and mildew and even sheet music that had been stored was ruined. In the choral department, costumes worn by school choruses were badly affected by mold and mildew requiring costly cleaning. Most significant, however, was the damage done to the grand piano in the choral department by excessive moisture in the air. Estimated overall costs due to the moisture-related damage to the Fine Arts Center were estimated to be between $35,000 and $45,000. The conventional air conditioning system was not sufficient to control the humidity levels in this building. A new solution had to be found.

BACKGROUND

Mountain Brook High School, the flagship of Mountain Brook School System is located in the city of Mountain Brook, Alabama, a very prestigious suburban community in the Birmingham area. Located in the southeastern United States, the school is subject to high temperatures and humidity levels from late spring through the middle fall months. For the school system, the situation is additionally challenging as the school is not open during the summer, and consequently the building is not air conditioned during peak temperature and humidity periods.

Figure 1. Mountain Brook High School

Like so many of the school buildings in operation today, the building's interior space is conditioned by conventional, packaged direct-expansion (DX) with only a thermostat controlling the environment. Furthermore, in an effort to save on the energy bills, one of two operational schemes is enabled during the summer months (or during the times when the building is unoccupied). First, the thermostat settings are placed around 80^0F, or higher, basically letting the temperature of the space float upwards requiring the cooling system to operate for fewer hours. Considering that the building will be unoccupied the majority of the time during this period, it would seem reasonable that there would not be a need to operate the cooling system. The second operating scenario is to completely shut off the cooling system, except for times when the space temperature exceeds that of the first operating scenario (i.e., setpoint at 80^0F degrees or so).

If saving energy were the only objective of the school system, then either of these operating scenarios might be fine. However, as the facility operators at Mountain Brook City Schools learned the hard way, regardless of the temperature requirements of the buildings during the summer months, the humidity must be *actively* controlled. Many operators and designers ignore the fact that dehumidification from a mechanical, or "conventional", system only occurs when the cooling coils are cold. The dehumidification requirement (latent conditioning) is secondary to the temperature control requirements of the building (sensible conditioning). In other words, the dehumidification control is merely a *passive* byproduct of the cooling needs being met.

In the geographical areas of this country that are hot and humid for many months of the year, such as the southeastern United States, near Birmingham where Mountain Brook is a suburb, this *passive* approach to controlling humidity will not work. Mountain Brook High School's Fine Arts Center, like most of the school buildings in operation today, relied on the cooling system to also control the humidity in the space. As in most other school buildings, there was not a humidistat, or any type of humidity sensor incorporated into the building's HVAC system.

In the past, the need to control the school's humidity levels didn't seem so important. However, with the requirements for increased ventilation rates in schools today, the risks of IAQ problems to the students, the school systems' personnel as well as their designers, combined with the hygroscopic nature of the volumes of books found in the schools' Media Centers and Fine Arts Centers, *active* humidity control has become much more of an important issue with which the designers must contend.

THE PROBLEM

Upon returning to school in the fall of 1998, significant problems were evident in the Fine Arts Center of the Mountain Brook High School. In the band department, black mold was found on ceiling tiles. Marching band uniforms were damaged beyond repair by mold and mildew. Sheet music that had been stored was ruined. In the choral department, costumes worn by school choruses were badly affected by mold and mildew requiring costly cleaning. Numerous awards and trophies also showed signs of uncontrolled moisture. Most significant was the damage done to the grand piano in the choral department by the excessive moisture in the air. Estimated overall costs to the school in this building due to the moisture-related damage were estimated to be between \$35,000 to \$45,000.

Two packaged DX air conditioning units were located on the roof condition the building. These units were scheduled to turn off during unoccupied times, such as summers and weekends. In addition, during most of the evenings during the school year, the HVAC systems were also scheduled to be off. As mentioned earlier, the temperature was allowed to "float" during these times when the building was unoccupied. Prior to occupancy, the systems would be scheduled to turn back on to bring the space temperature back to its "occupied" setpoint.

Figure 2. Fine Arts Center on Right Side

It is often assumed by building operators and designers that because the building is unoccupied and the exhaust fans in the building are shut off, the ventilation air to the building can be shut off also and the building will be "neutral" as far as pressurization is concerned. This is not necessarily true, depending on the wind and the external pressures it causes on the building's envelope. Even if the building were "neutral", or even slightly positively pressurized, this will not prevent excess moisture from infiltrating the building. Just as temperature travels from a hot surface, or area, to a cooler surface, or area, moisture migrates from an area of higher vapor pressure to an area of lower vapor pressure. A tight, or even a slightly pressurized building, only serves to slow down the migration of moisture into the building.

For example, assume that the school building was maintained at conditions of 75^0F drybulb and 50% rh (corresponding to a vapor pressure of approximately 0.44" Hg) until school was out for the day and the HVAC system was then scheduled off. That evening, it was raining and the ambient temperature was 70^0F drybulb. The vapor pressure outside would be approximately 0.75" Hg. This represents a difference of 0.31" Hg of pressure pushing the moisture into the building. This occurred throughout the summer and fall months at the school, causing the excess moisture to build up in the school resulting in mold, mildew and moisture damage to the building and its contents.

THE SOLUTION

While many solutions to the problem were evaluated, it was decided that an innovative desiccant-based outside air pre-treatment technology would be used to solve the school's moisture problem. A new desiccant dehumidification unit was added to each of the two existing rooftop air conditioning units on the roof providing a quick and easy solution. Humidity sensors were also added in the spaces to control the equipment. With the new outside air pre-treatment units, the latent load (moisture) from the ventilation air is removed *prior* to it entering the rooftop units. This pre-conditioning allows for the rooftop units to operate more efficiently and effectively, as they are only required to perform the sensible cooling. The building automation system still operates as before, shutting off the rooftop air conditioning units after-hours; however, in the event of the humidity levels in the spaces exceeding their setpoints, automation system is over-ridden and the desiccant dehumidification units are turned on as needed. The drier ventilation air is then delivered into the building via the respective rooftop air handler. Additionally, with the new desiccant-based outside air pre-treatment units, not only has the mold been eliminated, but also a much healthier environment has been created for the students. Due to the lower space moisture conditions, the space temperature can be maintained at a more comfortable (and higher) temperature (e.g., 76-77^{0}F drybulb), potentially saving significant energy dollars.

Figure 3. Desiccant Pre-conditioners

Figure 4. Close-up of Desiccant Unit

Had the system been designed into the school's HVAC system initially, provisions could have been made to include a set of dampers to allow for reduced amount of ventilation air to be introduced when in the "unoccupied" mode, and to allow for a large portion of the air to be recirculated from inside the building. This would obviously save significant energy dollars; however, in an effort to avoid any additional roof penetrations, and to minimize the capital costs to remedy the moisture problem, it was determined to simply apply these desiccant units upstream of the existing rooftop air conditioning units at this time.

THE DESICCANT TECHNOLOGY

The new desiccant technology that was chosen for the project combines the effects of a liquid desiccant process to remove the moisture (latent) with a conventional refrigeration circuit to reduce the sensible load. With the desiccant dehumidifiers, the ventilation air passes through the "process" side of the unit where it comes in contact with the lithium chloride (the desiccant medium), which is pouring down the cellulose media; the air is cooled as it gives up moisture to the desiccant liquid. The process of this new, innovative technology can be seen and described in greater detail in the following schematic.

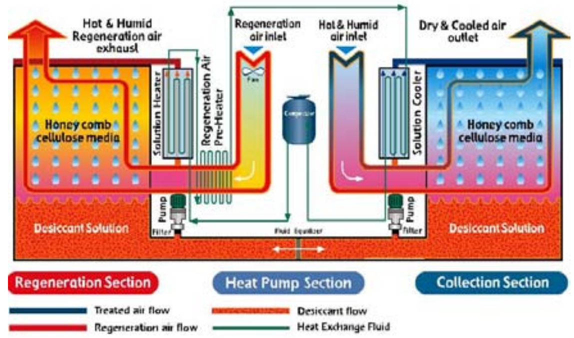

Figure 5. Schematic of Desiccant Dehumidifier

There are three main components to the installed liquid desiccant dehumidifier systems. First is the "collection" operation, often called the "process" side or "conditioning" side of an actively regenerated desiccant system. Here a cool, concentrated lithium chloride solution is continuously added to the top of the honeycomb cellulose material, which allows a liquid film to flow down (or "flood") the surface of the media. As the stream of air flowing in from the outside (often called process air) comes in contact with the cool, concentrated desiccant solution, the air's water molecules react with the lithium chloride solution and the air is cooled and dehumidified. The lithium chloride absorbs the moisture and generates heat (heat of sorption). As a result, the air flowing out of the process side is cooler and drier that when it entered the unit. This air is then introduced into the air handler system (i.e., the rooftop air handler) downstream where it will mix with the return air stream and can be further cooled if needed. The desiccant solution becomes warm and diluted as a result of this process.

Second is the heat exchange operation. Here the solution is pumped through a strainer and a plate heat exchanger. By using a refrigeration circuit, the heat created during the collection operation is transferred to the regeneration operation. The heat is necessary for the regeneration of the diluted lithium chloride solution.

The third and final component concerns the regeneration operation. This operation is similar to the collection process except that the lithium chloride solution is now heated to remove the moisture previously collected from the outside air stream. The heated, diluted solution is continuously added to the top of the media on the regeneration side. As in the collection operation the solution forms a liquid film that flows over the surface of the cellulose media. As a stream of outside air passes through the media, often called "scavenger air", the excess moisture and heat in the solution is released into the air stream and exhausted outside. As a result of the regeneration operation, the lithium chloride solution is restored to its original density.[1]

Unlike conventional DX air conditioning systems that may suffer in capacity reduction as the outdoor air temperature increases in temperature and moisture content, this innovative desiccant technology actually will become more efficient as the outdoor conditions increase in temperature and humidity. Another unique feature of this technology, which combines the benefits and attributes of both a desiccant process and the DX process, is that sensible cooling is also provided as a by-product with no additional expense. This benefit results in energy savings to the school.

OTHER CONSIDERATIONS

Considering the following "Mold Square" diagram, we understand that if we can eliminate any one of the four sides to the square, we can effectively eliminate the potential moisture-related problems within our buildings. Mold spores are everywhere, even in the air that we breathe. The food for these mold spores is more than abundant inside our buildings (e.g., carpet fibers, wall paper paste, etc.). The temperatures in which we are comfortable in our buildings are within the range necessary for mold growth (i.e., 40F to 120F). The only element we can *control* is the moisture. If we know from the numerous studies and reports that excessive moisture in a building is a leading cause of indoor air quality problems, and that most of this moisture is introduced by way of the ventilation air, then doesn't it make sense to remove the excess moisture from the ventilation air *before* it is introduced into the building? This is exactly what the desiccant system installed at the Mountain Brook Fine Arts Center was designed to do.

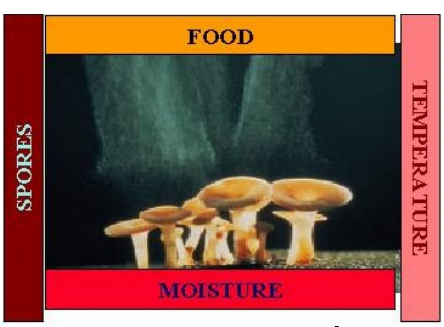

Figure 6. Mold Square[2]

From the chart shown below we can see the optimum humidity levels desired within our building spaces in order to maintain healthy environments. We have known for many years the affects of varying humidity levels inside a building on a person's comfort, but due to recent studies relating humidity levels to their affect on a person's health we now have even more reason to *actively* control and *monitor* the humidity levels within our buildings.

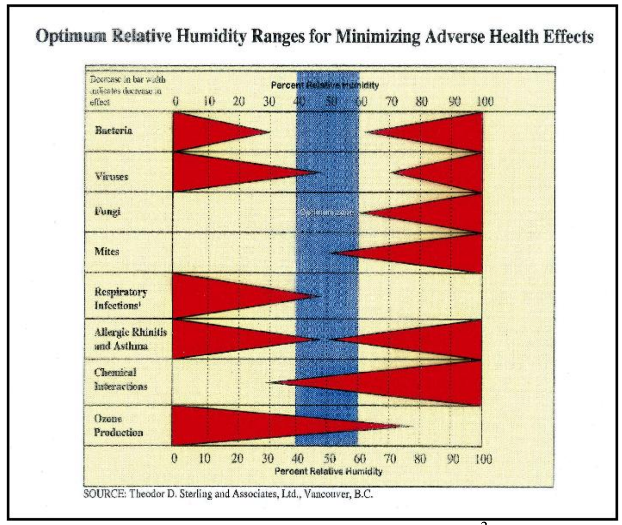

Figure 7. Optimum Humidity Range[3]

While little attention has been paid to *active* humidity control in the past in most school HVAC system designs, this must no longer be the case. Since 1997, ASHRAE has published in its *Fundamentals Handbook* additional historical weather data for many of the major cities of the world. No longer does the handbook only include information for the peak *sensible* conditions for a particular city (i.e., Drybulb/Mean Coincident Wetbulb), but also now includes information concerning the peak *latent* conditions for the same cities (i.e., Dewpoint / Humidity Ratio and Mean Coincident Drybulb)[4]. This new data should always be considered when designing for humidity control and for ventilation air conditioning.

Considering these extreme weather conditions for the Birmingham, Alabama area during the design and selection of the desiccant dehumidification units' addition to the school's existing HVAC system, the space within the Fine Arts Center for Mountain Brook High School can now be maintained at satisfactory levels when the ventilation air is pre-conditioned to a much lower absolute moisture level.

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